IAEA EXPERIENCE WITH ENVIRONMENTAL SAMPLING AT GAS CENTRIFUGE ENRICHMENT PLANTS IN THE EUROPEAN UNION

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Abstract

Environmental sampling has been used routinely by the IAEA since 1996 after the IAEA Board of Governors approved it in March 1995 as a new technique to strengthen safeguards and improve efficiency. In enrichment plants it is used to confirm that there has been no production of highly enriched uranium (HEU) or production of uranium above the declared enrichment. Since the implementation of environmental sampling, swipe samples have been collected from 240 sampling points at three gas centrifuge plants in the European Union (EU) which have a total throughput of more than 8,000 tonnes of low enriched uranium per year. The environmental sampling results generally reflected the known operational history of the plants and confirmed that they had only been operated to produce uranium with enrichment less than 5% ^{235}U. The results, which also provided information about the content of the minor isotopes ^{234}U and ^{236}U, indicated that depleted and recycled uranium was sometimes used as feed material in some plants.

1. INTRODUCTION

The fundamental objective of safeguards at uranium enrichment plants is to detect undeclared production of HEU and other undeclared enrichments or activities. This is reflected in Article 6(c) of INFCIRC/153 (concentration of verification procedures on fuel cycle stages involving or capable of producing direct-use material) and was an important element of the Hexapartite Safeguards Project (HSP) conclusions. The safeguards approach implemented at enrichment plants since the conclusion of the HSP includes Limited Frequency Unannounced Access (LFUA) to the cascade areas during which visual observation, application of surveillance systems, and non-destructive assay (NDA) measurements have been carried out. At the time of the HSP deliberations, environmental sampling (ES) did not exist as a viable option. However, since then it has been developed as a powerful, complementary tool capable of detecting production of HEU and other enrichments greater than declared. While no one of these measures meets all relevant objectives, a combination of them optimised to facility specific conditions is recommended as the safeguards approach for enrichment plants.

The use of ES is based on the assumption that every process, no matter how leak tight, will release small amounts of process material to the environment. Even though these releases of nuclear material are extremely small in gas centrifuge enrichment plants, and well below levels of concern from a health physics and safety standpoint, they are detectable and their analysis provides an indication of the enrichment of the material that has been processed in the plant.

Environmental samples at enrichment plants are collected by swiping selected areas of the plant with squares of cotton cloth (10x10cm) from sampling kits prepared in ultra clean conditions. The squares of cotton cloth sealed in plastic bags are sent for analysis to the Safeguards Analytical Laboratory (SAL) and/or the Network Analytical Laboratories (NWAL). The analysis includes the measurement of uranium isotopic composition in uranium-containing particles by Thermal Ionisation Mass Spectrometry (TIMS) or Secondary Ion Mass Spectrometry (SIMS).

2. EFFECTIVENESS

At centrifuge enrichment plants in the EU, Agency ES has proven effective in detecting all enrichments declared by the operators in the production of low enriched uranium. Field trial results of High Precision Trace Analysis (HPTA), i.e. ES, reported by Euratom and the European Joint Research Centre in Karlsruhe, Germany, also demonstrated clear signatures of past operations [1].

Figure 1 shows an example of the TIMS particle results obtained for two samples taken in May 1997 from the cascade hall at one of the URENCO enrichment plants. The evaluation of the results, using model enrichment calculations, showed that two different feed materials, natural uranium (NU) and recycled uranium, were used. In the graph ^{234}U vs. ^{235}U, the upper enrichment line represents the feeding of recycled uranium to cascades. The lower enrichment line represents feeding of natural uranium. The graph ^{236}U vs. ^{235}U also shows the expected enrichment line of recycled uranium.

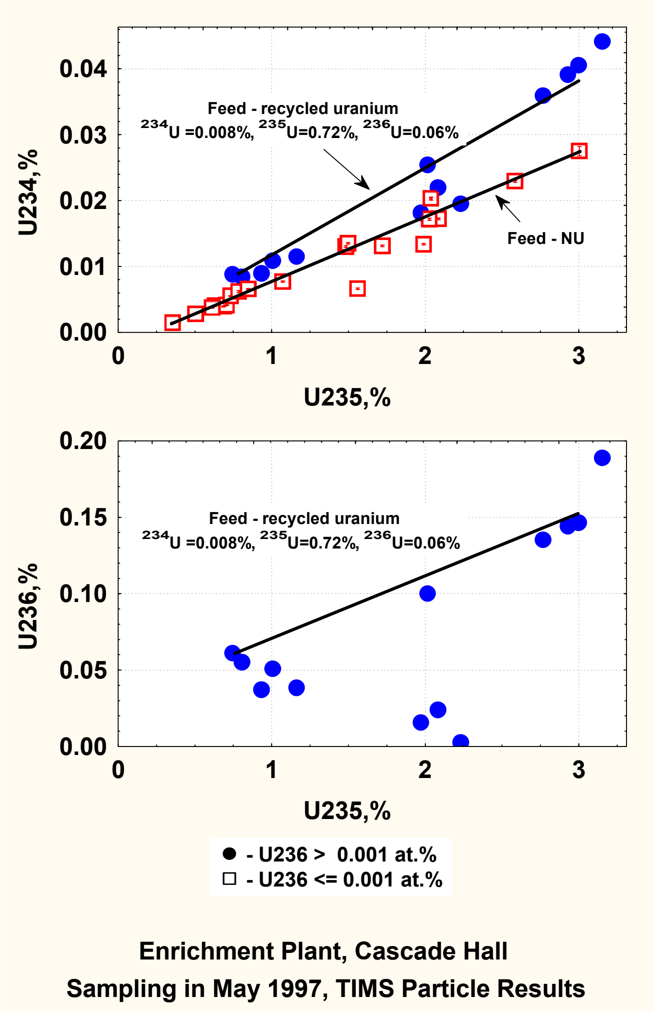


Figure 1

The effectiveness of ES was also demonstrated by analysing a series of swipe samples taken at regular intervals in the process area of a newly commissioned centrifuge enrichment cascade in which the product enrichment was increased stepwise to 5% ^{235}U [2]. The results showed clear indicators of new production after the enrichment level was increased. Figure 2 shows three consecutive sampling dates and the corresponding production enrichments.

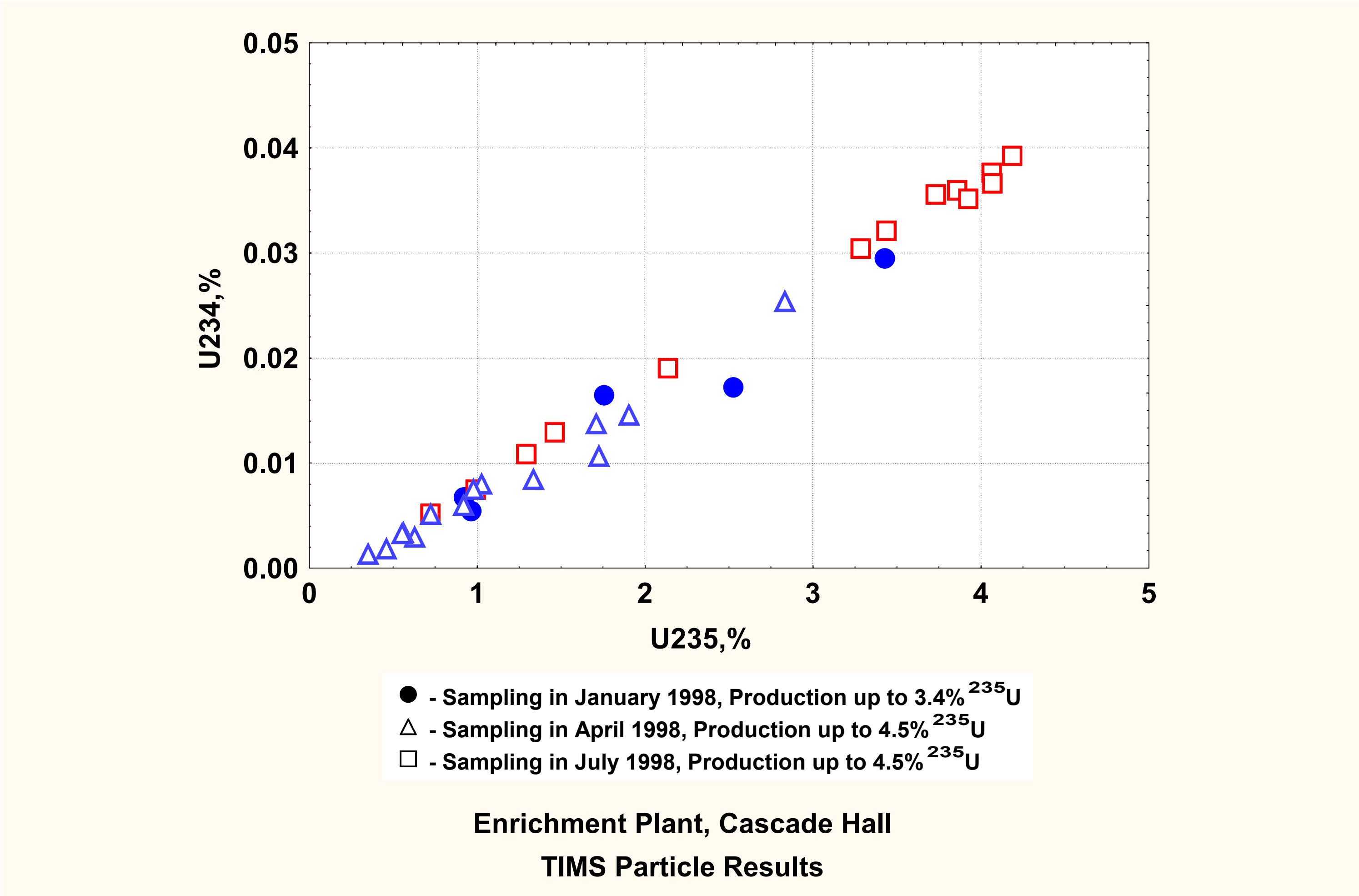


Figure 2

The sampling in April 1998 did not detect the 4.5% production enrichment that began a month earlier. However, it was detected in the July 1998 sampling campaign.

3. TIMELY DETECTION

ES clearly demonstrated its effectiveness in eventually detecting the occurrence of changes in produced enrichments [2]. The Agency's timeliness goal for detection of undeclared production of HEU is one month. The actual detection time for ES includes the following time intervals:

(a) Actual production enrichment change,
(b) Release and settling of particles in the plant,
(c) Swipe sample taking and transport to HQs,
(d) Sample separation and distribution to NWAL,
(e) Sample preparation and measurement,
(f) Receipt of results at HQs,
(g) Evaluation and interpretation.

These time intervals contribute to the overall detection time, e.g., from the change in production enrichment, e.g., undeclared production of HEU, to detection by ES. On a test case basis and for a limited number of samples the NWAL successfully reduced the time from swipe sample taking through reporting of initial analytical results to one month. The limited test does not demonstrate that the timeliness goal can be achieved on a routine basis. The test did not include determining the period from production change to release and settling of the particles in the plant. However based on the results from [2], the time required for particles to be released and settled is estimated to be from one to six weeks. Therefore, a routine detection time of three months appears achievable. Though the IAEA cannot attain its current timeliness goal, such a detection time is a formidable deterrent to a possible divertor. Also sampling at shorter time intervals would increase the deterrent effect of ES.

4. SOURCES OF UNEXPECTED PARTICLE RESULTS

UF_6 cylinders containing all categories of uranium are shipped worldwide between enrichment plants and their customers, and between the enrichment plants themselves. These cylinders can be a source of unexpected particle results. An exercise to assess the risk of cross-contamination by these cylinders was carried out at two of the enrichment plants. Three UF_6 cylinders with a known history of shipments were externally swipe-sampled at different EU plants. Two of them that were relatively new had been filled with 4.4% LEU at an enrichment plant outside the EU before being emptied at one plant in the EU. The third cylinder had travelled more extensively both in and outside the EU. The ES analyses detected not only enrichments of feed or product at the plants, but also some particles with enrichments higher than declared. As expected, the 4.4% enrichment was also detected (see Figure 3). It was deduced that cross-contamination had occurred and therefore it is strongly recommended that routine sampling of UF_6 cylinders and their storage locations should be avoided.

At one EU centrifuge plant, higher enrichments produced more than 20 years ago in an adjacent, now decommissioned, gaseous diffusion plant have also been detected [2]. In these data sets, the relative frequency of particles representing current production is significantly higher than that of particles representing historical production.

Another possible source of unexpected particle results is personnel moving between plants. These personnel may carry a few particles through their movements. This is one reason for not drawing conclusions from a single particle result. However, the strict sampling protocol followed by inspectors carrying out ES should minimize the risk of cross-contamination.

5. EVALUATION OF UNEXPECTED PARTICLE RESULTS

Prior to the implementation of routine ES for safeguards purposes, a campaign of baseline ES was carried out to establish the enrichment signatures existing at each EU enrichment plant. During baseline sampling numerous swipes were taken from each EU plant. Since then, a significantly lower number of swipes have been taken and analysed. The evaluation of these subsequent ES results allows conclusions to be drawn about consistency with the baseline and

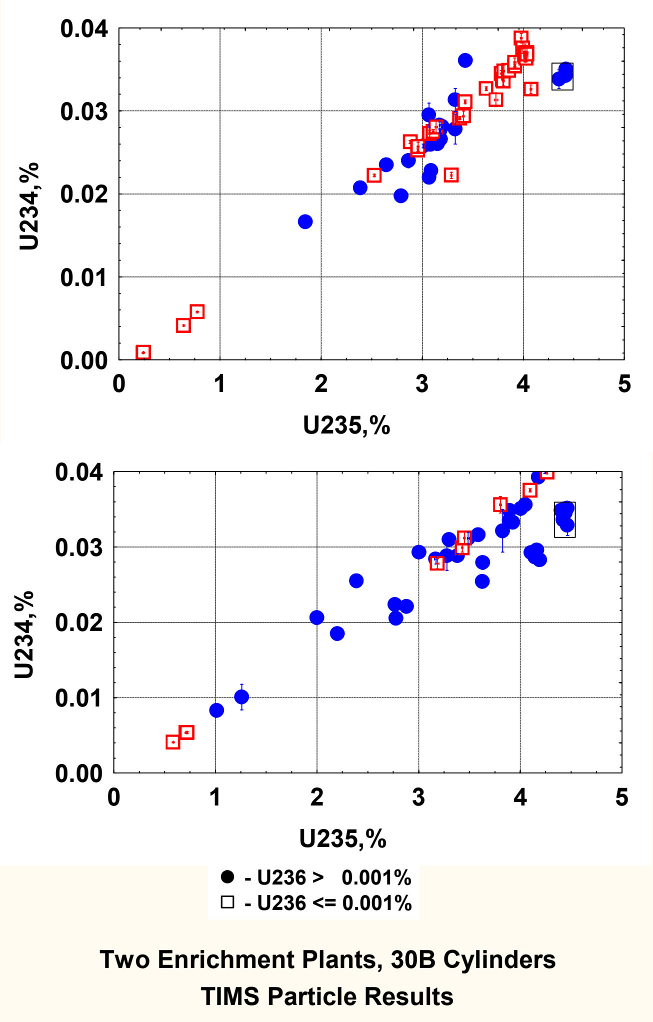


Figure 3

the declared enrichments. However, one should note that the baseline might not be representative in the statistical sense. Despite numerous swipes collected during the baseline campaign material existing at the facility may not have been detected. Therefore, the existence of unexpected particle results, not detected in the baseline results, is not necessarily evidence of undeclared enrichments as long as the results fall within the expected range. One example is given in Figure 4. The facility only uses commercial grade natural UF_6, which may contain up to 0.002% ^{236}U. Therefore 5% LEU produced from commercial grade NU may contain up to 0.01% ^{236}U. In Figure 4 one observes many particles with relatively high ^{236}U abundance and those above the line are considered to be from other sources, e.g., from the neighbouring decommissioned gaseous diffusion plant.

This example also demonstrates the importance of measuring minor isotopes in explaining particles that may have been carried over from other locations and for separating current production activities from historical activities.

5.1 Follow up actions

From the discussion above, the occurrence of unexpected particle results outside the declared enrichment range is not by itself an indicator of production of undeclared enrichments. Careful follow-up and evaluation is required. The follow-up actions should include:

(a) Re-confirm results by SAL and NWAL,
(b) Analyse archive and control samples,
(c) Re-sample specific or related plant locations,
(d) Compare with the established baseline,
(e) Analyse minor isotopes,
(f) Contact operator for further explanations.

Conclusions should not be based on a single particle result, although it may trigger further follow-up actions. Another reason for not drawing conclusions from a single particle result is that transient production of enrichments higher than planned may occasionally occur during start-up.

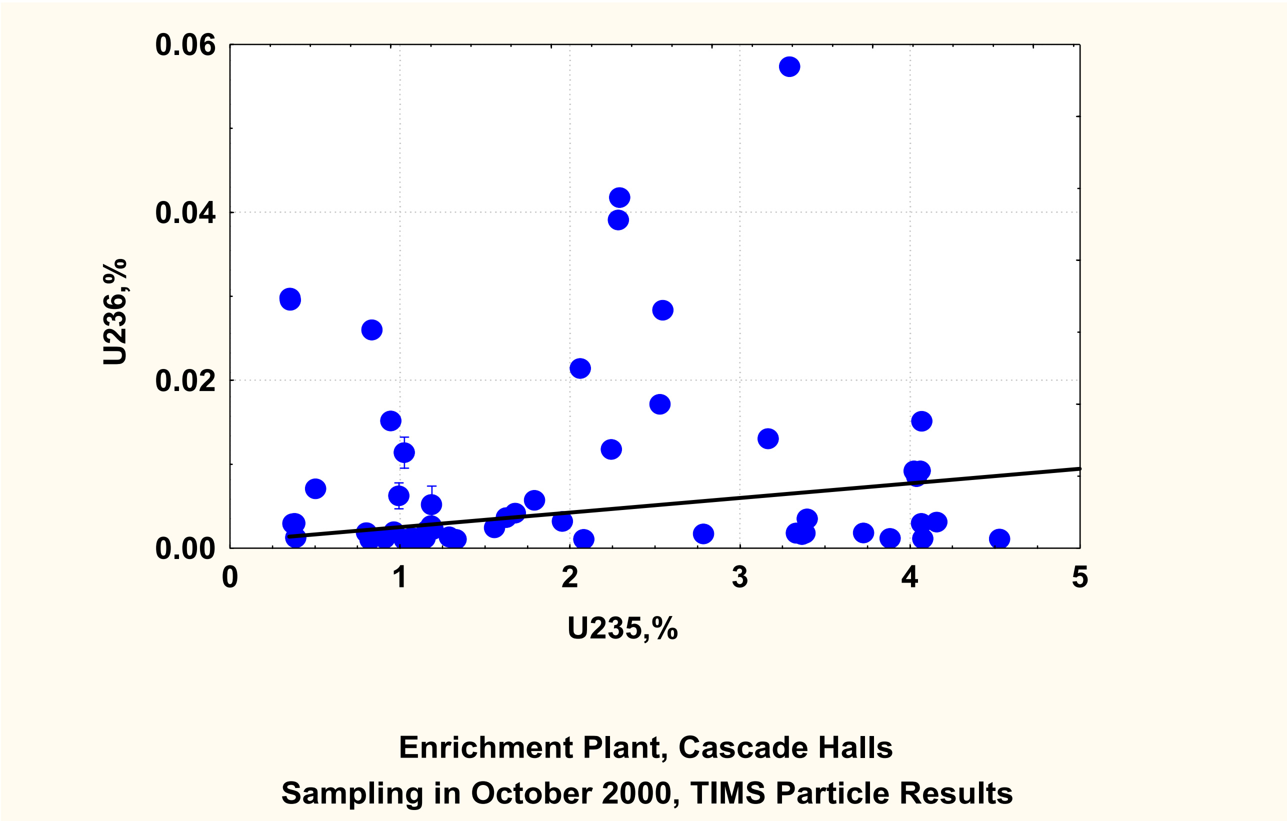
5.2 Credible Explanations

The following are considered credible explanations for particles detected above the declared enrichment. Such results may be due to the carry over of particles from:

(a) Past activities with enrichments higher than current production,
(b) Transport of cylinders,
(c) People,
(d) Imported equipment or process components,
(e) Transients from centrifuge start-up.

An anomaly is confirmed only when a significant deviation from the baseline is observed and all possible explanations become implausible.

Figure 4



6. EXPOSURE TO SENSITIVE TECHNOLOGY

Environmental swipe sampling inside the cascade halls is essential for the effective implementation of the method. Modifying cascade configurations or temporarily adding additional feed or withdrawal points inside the cascades are possible scenarios for the undeclared production of HEU. Release of particles during these modifications is highly likely.

Swipe sampling is performed during LFUAs to the cascade areas along the access routes defined for them. Therefore, no additional accesses to the cascades are foreseen other than those already carried out under HSP. Should additional access be required for possible anomaly follow-up, then exposure to sensitive technology could be overcome by preventing direct visual observation of the centrifuges and sensitive pipe works by shrouding during environmental sampling.

Conducting environmental swipe sampling will not increase the exposure to sensitive enrichment technology beyond that already agreed in current safeguards approaches.

7. CONCLUSIONS

Experience is still being gained with environmental sampling at centrifuge enrichment plants, but it has already proved to be an effective technique, which allows determining past and current enrichment activities, in particular providing complementary assurance that no clandestine HEU production has occurred. Sampling both inside cascade areas and in cylinder filling and blending areas has proven to be useful and appropriate without additional exposure to sensitive enrichment technology.

It should be recognised that the risk of cross-contamination exists and needs to be taken into account in the sampling protocols, in selecting locations for sampling, and in the evaluation of any possible unexpected particle results. A single particle result should not be the basis for drawing conclusions, but could trigger further follow-up actions.

The IAEA has demonstrated it can significantly reduce the time required from sample taking to evaluating measured particle results. However, it is not yet able to attain on a routine basis its one-month timeliness goal for the detection of the undeclared production of HEU through the application of environmental sampling.

A safeguards approach based on the traditional safeguards measures combined with environmental sampling for routine use is currently under development with the Euratom Safeguards Office in Luxembourg. This approach will increase the probability of detecting clandestine activities and enhance the efficiency of inspectors' work in the field.

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